Highly Resistive ZnO / Cu Multi-layered Film by Solution Chemical Processes

Hisaya Takahashi
NEC Toyama, Ltd.
560 Nyuzen, Nyuzen-machi, Shimoniikawa-gun,
Toyama 939-0626, Japan
E-mail: takahasi@tnec.nec.co.jp
Masanobu Izaki
Osaka Municipal Technical Research Institute
1-6-50 Morinomiya, Joto-ku, Osaka 536, Japan
E-mail: izaki@omtri.city.osaka.jp

Introduction

Zinc Oxide (ZnO) is a n-type semiconductor with a direct band gap energy of 3.3eV and the film is prepared by chemical reaction from an aqueous solution as we already demonstrated. The film showed high optical transparency of around 80% and resistivity of the order of $10^3\Omega$cm. Some amount of copper (Cu^+) ion was incorporated into ZnO film by immersing in a simple copper sulfate solution at ambient temperature and gave increased resistivity. And immersing the Cu:ZnO film into potassium borohydride aqueous solution gave the reduction of Cu^+ ion to Cu^0 state and formation of metallic Cu layer.

In this paper, we demonstrated the preparation of multi-layered structure of ZnO and Cu layers by repeating the formation of ZnO and Cu layers. Electrical and structural characterizations were performed with X-ray diffraction, SEM observation, and measurements of electrical resistivity.

Experimental procedure

200nm-thick-ZnO film was deposited chemically onto Corning #1737 glass substrates by immersing into an aqueous solution containing zinc nitrate hydrous and DMAB maintained at 60°C without stirring. Prior to the deposition, the substrates were activated with an industrially employed Pd/Sn catalytic activation process. Metallic Cu layer was prepared at an ambient temperature by immersing the ZnO film into 10mM copper sulfate aqueous solution and then immersing into potassium borohydride (KBH_4) aqueous solution.

Results and Discussion

Fig. 1 showed resistivity of ZnO film immersed into copper sulfate aqueous solution as a function of immersing time. The resistivity of Cu incorporated ZnO film increased with the increase in immersing time and the maximum value of $2x10^8\Omega$cm was obtained at immersing time of 30sec. Immersing the Cu:ZnO film into KBH_4 solution gave the formation of Cu layer with the resistivity of the order of $10^{-5}\Omega$cm, which was slightly higher than the value for bulk material, because of the small grain size and non-uniform strain. The depth profiles taken with an X-ray photoelectron spectroscopy(XPS) exhibited that ZnO layer containing some amount of Cu ion was remained under metallic Cu layer.

ZnO layer was growing up onto the metallic Cu layer without any activation process only by immersing into zinc nitrate and DMAB solution. The deposition rate was about twice that for the activated glass substrate. Fig.2 showed a SEM photograph for cross-sectioned structure of ZnO/Cu multi-layered film, which was prepared by repeating three times the formation of ZnO layer and Cu layer.

In conclusion, a multi-layered ZnO/Cu layer could be prepared by using the method of mentioned above and the process will be a candidate for preparing multi-layered printed circuit board.

Reference

1)M. Izaki, et al, Appl. Phys. Lett, 68, 2439 (1996).
2)M. Izaki, et al., J. Electrochem. Soc., 146, 4517(1999).
3)M. Izaki, et al, ibid, 147, 210(2000).
4)M. Izaki, H. Takahashi, et. al, Electrochem. Solid State lett., 3, 501(2000).

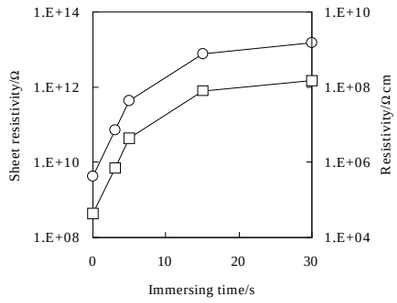

Fig.1 Sheet resistivity and resistivity for Cu:ZnO films

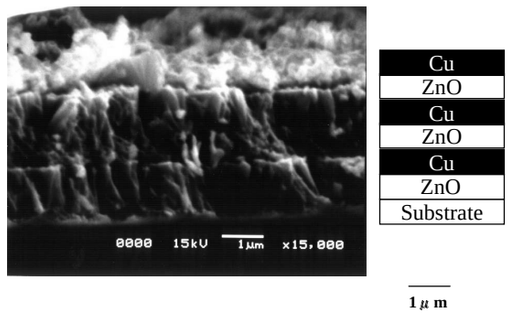

Fig.2 Cross-sectional image for $(ZnO/Cu)_3$ layered films